



PCT

NOTIFICATION OF THE RECORDING
OF A CHANGE(PCT Rule 92bis.1 and
Administrative Instructions, Section 422)

From the INTERNATIONAL BUREAU

To:

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Leonhard Olgemöller Fricke
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Date of mailing (day/month/year)

05 September 2000 (05.09.00)

Applicant's or agent's file reference

10645q

International application No.

PCT/EP00/06202

International filing date (day/month/year)

03 July 2000 (03.07.00)

IMPORTANT NOTIFICATION

1. The following indications appeared on record concerning:



the applicant



the inventor



the agent



the common representative

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State of Residence

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Teleprinter No.

2. The International Bureau hereby notifies the applicant that the following change has been recorded concerning:



the person



the name



the address



the nationality



the residence

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State of Nationality

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State of Residence

DE

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3. Further observations, if necessary:

4. A copy of this notification has been sent to:



the receiving Office



the International Searching Authority



the International Preliminary Examining Authority



the designated Offices concerned



the elected Offices concerned



other:

The International Bureau of WIPO
34, chemin des Colombettes
1211 Geneva 20, Switzerland

Facsimile No.: (41-22) 740.14.35

Authorized officer

Lazar Joseph Panakal

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REC'D 04 SEP 2001

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WIPO

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INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

14

Applicant's or agent's file reference 10645q	FOR FURTHER ACTION See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416)	
International application No. PCT/EP00/06202	International filing date (day/month/year) 03/07/2000	Priority date (day/month/year) 01/07/1999
International Patent Classification (IPC) or national classification and IPC G02B1/04		
Applicant FRAUNHOFER-GESELLSCHAFT ZUR FÖRDERUNG... et al.		
<p>1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.</p> <p>2. This REPORT consists of a total of 4 sheets, including this cover sheet.</p> <p><input checked="" type="checkbox"/> This report is also accompanied by ANNEXES, i.e. sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).</p> <p>These annexes consist of a total of 4 sheets.</p>		
<p>3. This report contains indications relating to the following items:</p> <ul style="list-style-type: none">I <input checked="" type="checkbox"/> Basis of the reportII <input type="checkbox"/> PriorityIII <input type="checkbox"/> Non-establishment of opinion with regard to novelty, inventive step and industrial applicabilityIV <input type="checkbox"/> Lack of unity of inventionV <input checked="" type="checkbox"/> Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statementVI <input type="checkbox"/> Certain documents citedVII <input type="checkbox"/> Certain defects in the international applicationVIII <input type="checkbox"/> Certain observations on the international application		
Date of submission of the demand 24/01/2001	Date of completion of this report 31.08.2001	
Name and mailing address of the international preliminary examining authority:  European Patent Office D-80298 Munich Tel. +49 89 2399 - 0 Tx: 523656 epmu d Fax: +49 89 2399 - 4465	Authorized officer Ludi, M Telephone No. +49 89 2399 2229 	

**INTERNATIONAL PRELIMINARY
EXAMINATION REPORT**

International application No. PCT/EP00/06202

I. Basis of the report

1. With regard to the **elements** of the international application (*Replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report since they do not contain amendments (Rules 70.16 and 70.17)*):

Description, pages:

1-11 as originally filed

Claims, No.:

1-23 as received on 06/07/2001 with letter of 06/07/2001

Drawings, sheets:

1/1 as originally filed

2. With regard to the **language**, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.

These elements were available or furnished to this Authority in the following language: , which is:

- ☐ the language of a translation furnished for the purposes of the international search (under Rule 23.1(b)).
☐ the language of publication of the international application (under Rule 48.3(b)).
☐ the language of a translation furnished for the purposes of international preliminary examination (under Rule 55.2 and/or 55.3).

3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international preliminary examination was carried out on the basis of the sequence listing:

- ☐ contained in the international application in written form.
☐ filed together with the international application in computer readable form.
☐ furnished subsequently to this Authority in written form.
☐ furnished subsequently to this Authority in computer readable form.
☐ The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.
☐ The statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished.

4. The amendments have resulted in the cancellation of:

- ☐ the description, pages:
☐ the claims, Nos.:

**INTERNATIONAL PRELIMINARY
EXAMINATION REPORT**

International application No. PCT/EP00/06202

☐ the drawings, sheets:

5. ☐ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed (Rule 70.2(c)):

(Any replacement sheet containing such amendments must be referred to under item 1 and annexed to this report.)

6. Additional observations, if necessary:

**V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability;
citations and explanations supporting such statement**

1. Statement

Novelty (N)	Yes:	Claims	1-23
	No:	Claims	
Inventive step (IS)	Yes:	Claims	1-23
	No:	Claims	
Industrial applicability (IA)	Yes:	Claims	1-23
	No:	Claims	

2. Citations and explanations
see separate sheet

**INTERNATIONAL PRELIMINARY
EXAMINATION REPORT - SEPARATE SHEET**

International application No. PCT/EP00/06202

Re It m V

Reasoned statement under article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

- 1). Reference is made to the following document:

D1: EP-A-0 499 492

- 2). D1 discloses plastic optical articles which have transparent coating film applied to a transparent three-dimensional cross-linked resin that is neither polycyanate resin, nor polycyanurate resin; such article can be used as substrate material for display devices, see D1, example 1, page 8, lines 36-42.

Thus, the subject-matter of claims 1 is therefore novel, article 33 (2) PCT.

- 3). The problem underlying the present application may be regarded as the provision of thermal or thermo-mechanical long-term substrates for optical systems.

The solution proposed in claim 1 of the present application can be considered as involving an inventive step (article 33(3) PCT) since it cannot be deduced from the disclosure of D1.

- 4). Claims 2-23 are dependent on or refer back to claim 1 and as such also meet the requirements of the PCT with respect to novelty and inventive step.

INTERNATIONAL SEARCH REPORT

(PCT Article 18 and Rules 43 and 44)

Applicant's or agent's file reference 10645q	FOR FURTHER ACTION see Notification of Transmittal of International Search Report (Form PCT/ISA/220) as well as, where applicable, item 5 below.	
International application No. PCT/EP 00/06202	International filing date (day/month/year) 03/07/2000	(Earliest) Priority Date (day/month/year) 01/07/1999
Applicant FRAUNHOFER-GESELLSCHAFT ZUR FÖRDERUNG DER ...		

This International Search Report has been prepared by this International Searching Authority and is transmitted to the applicant according to Article 18. A copy is being transmitted to the International Bureau.

This International Search Report consists of a total of 3 sheets.



It is also accompanied by a copy of each prior art document cited in this report.

1. Basis of the report

- a. With regard to the **language**, the international search was carried out on the basis of the international application in the language in which it was filed, unless otherwise indicated under this item.



the international search was carried out on the basis of a translation of the international application furnished to this Authority (Rule 23.1(b)).

- b. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international search was carried out on the basis of the sequence listing :



contained in the international application in written form.



filed together with the international application in computer readable form.



furnished subsequently to this Authority in written form.



furnished subsequently to this Authority in computer readable form.



the statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.



the statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished

2. ☐ **Certain claims were found unsearchable** (See Box I).

3. ☐ **Unity of invention is lacking** (see Box II).

4. With regard to the **title**,



the text is approved as submitted by the applicant.



the text has been established by this Authority to read as follows:

5. With regard to the **abstract**,



the text is approved as submitted by the applicant.



the text has been established, according to Rule 38.2(b), by this Authority as it appears in Box III. The applicant may, within one month from the date of mailing of this international search report, submit comments to this Authority.

6. The figure of the **drawings** to be published with the abstract is Figure No.



as suggested by the applicant.



because the applicant failed to suggest a figure.



because this figure better characterizes the invention.



None of the figures.

INTERNATIONAL SEARCH REPORT

International Application No

PCT/EP 00/06202

A. CLASSIFICATION OF SUBJECT MATTER

IPC 7 G02B1/04

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 G02B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

WPI Data, PAJ, EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 0 499 492 A (TORAY INDUSTRIES) 19 August 1992 (1992-08-19) claims 1,9 page 2, line 26 -page 4, line 17 page 8, line 36 - line 42 page 10; example 1 ---	1,3,11, 17,19
X	EP 0 436 115 A (DOW CHEMICAL CO) 10 July 1991 (1991-07-10) claims 1,4 page 9, line 6 - line 35 ---	1
X	WO 85 04780 A (AMERICAN TELEPHONE & TELEGRAPH) 24 October 1985 (1985-10-24) claim 1 page 2, line 19 - line 28 ---	1
	-/--	

☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

° Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search

31 October 2000

Date of mailing of the international search report

13/11/2000

Name and mailing address of the ISA

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Authorized officer

Depijper, R

INTERNATIONAL SEARCH REPORT

International Application No

PCT/EP 00/06202

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 96 17020 A (ALLIED SIGNAL INC) 6 June 1996 (1996-06-06) claim 1 page 18, line 5 - line 8 page 27; table 3 ---	1
A	US 5 246 782 A (CLEMENT KATHERINE S ET AL) 21 September 1993 (1993-09-21) claims 1,2,4,12,14,15,21 column 2, line 23 - line 36 column 14, line 58 - line 60 column 20, line 63 -column 21, line 2 ---	1,3,11, 17,19
A	US 4 604 435 A (KOSHII TARO ET AL) 5 August 1986 (1986-08-05) claim 1 column 1, line 5 - line 10 -----	5

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/EP 00/06202

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 0499492 A	19-08-1992	AU 652220 B	18-08-1994
		AU 1091092 A	20-08-1992
		DE 69216651 D	27-02-1997
		DE 69216651 T	07-05-1997
		JP 5086221 A	06-04-1993
		KR 195774 B	15-06-1999
		US 5514466 A	07-05-1996
EP 0436115 A	10-07-1991	BR 9006150 A	24-09-1991
		CA 2030878 A	28-05-1991
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		JP 3179431 A	05-08-1991
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		US 5173546 A	22-12-1992
		US 5273793 A	28-12-1993
WO 8504780 A	24-10-1985	US 4554229 A	19-11-1985
		CA 1254789 A	30-05-1989
		DE 3566767 D	12-01-1989
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		JP 4047475 B	04-08-1992
		JP 61501806 T	21-08-1986
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WO 9617020 A	06-06-1996	US 5912308 A	15-06-1999
		AT 170899 T	15-09-1998
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		CN 1166849 A	03-12-1997
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		DK 794979 T	01-03-1999
		EP 0794979 A	17-09-1997
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		NO 972462 A	29-07-1997
		PL 320741 A	27-10-1997
		US 5922448 A	13-07-1999
		ZA 9510156 A	30-05-1996
US 5246782 A	21-09-1993	CA 2057309 A	11-06-1992
		EP 0490335 A	17-06-1992
		JP 4325237 A	13-11-1992
		US 5364547 A	15-11-1994
		US 5409777 A	25-04-1995
		US 5730922 A	24-03-1998
US 4604435 A	05-08-1986	JP 60115619 A	22-06-1985
		CA 1225770 A	18-08-1987
		DE 3470050 D	28-04-1988
		EP 0146803 A	03-07-1985
		US RE32958 E	20-06-1989

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau



(43) International Publication Date
11 January 2001 (11.01.2001)

PCT

(10) International Publication Number
WO 01/02878 A1

- (51) International Patent Classification⁷: **G02B 1/04** (74) Agents: **OLGEMÖLLER, Luitgard** et al.; Leonhard Olgemöller Fricke, Postfach 10 09 57, D-80083 München (DE).
- (21) International Application Number: **PCT/EP00/06202**
- (22) International Filing Date: **3 July 2000 (03.07.2000)** (81) Designated States (*national*): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, BZ, CA, CH, CN, CR, CU, CZ, DE, DK, DM, DZ, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, TZ, UA, UG, US, UZ, VN, YU, ZA, ZW.
- (25) Filing Language: **English**
- (26) Publication Language: **English**
- (30) Priority Data:
99112602.0 **1 July 1999 (01.07.1999)** EP (84) Designated States (*regional*): ARIPO patent (GH, GM, KE, LS, MW, MZ, SD, SL, SZ, TZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).
- (71) Applicant (*for all designated States except US*): **FRAUNHOFER-GESELLSCHAFT ZUR FÖRDERUNG DER ANGEWANDTEN FORSCHUNG E.V. [DE/DE]**; Leonrodstrasse 54, D-80636 München (DE).
- (72) Inventors; and
- (75) Inventors/Applicants (*for US only*): **BAUER, Monika** [DE/DE]; Wendenstrasse 40, D-15754 Senzig (DE). **BAUER, Jörg** [DE/DE]; Wendenstrasse 40, D-15754 Senzig (DE). **DREYER, Christian** [DE/DE]; Hauptstraße 53a, D-55758 Neiderwörresbach (DE). **KEIL, Norbert** [DE/DE]; Nieplitzsteig 11a, D-14089 Berlin (DE). **ZAWADZKI, Crispin** [DE/DE]; Pechsteinstrasse 80, D-12309 Berlin (DE).
- Published:**
- With international search report.
 - Before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments.
- For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.*



WO 01/02878 A1

(54) Title: **THERMOSETTING PLASTICS AS SUBSTRATE MATERIALS FOR OPTICAL SYSTEMS**

(57) Abstract: The present invention relates to the use of a thermosetting plastic as a substrate material in optical systems. The optical system may be e.g. a waveguide system or an electro-optical actuator or a thermo-optical actuator. Preferably the thermosetting plastic is selected from polycyanate resins and polycyanurate resins. It is especially preferred to add a material having higher conductivity to the thermosetting plastic in order to obtain a substrate having an increased thermal conductivity for carrying thermo-optical actuators and the like.

Thermosetting plastics as substrate materials for optical systems

The present invention is directed to optical instruments and systems, e.g. wave guides or wave guide systems, which comprise organic polymers as optical elements, applied to suitable substrates. Specifically, the substrates consist of or comprise thermosetting plastics.

Organic polymers are increasingly interesting materials in the optical or microoptical field, in integrated optics or in microsystem techniques. In these fields, they may be used in optical instruments and apparatuses or parts thereof as well as in special optics as lenses, prisms, for fixation of optical systems, as support material for optical layers and as translucent coating materials for mirrors or lenses. Organic polymers may be used in optical fibres and for the preparation of waveguide structures. Their technical handling is relatively easy, and their density is lower in comparison to glass.

Specifically, if different optical elements are to be integrated on a chip, e.g. of electro-optical or thermo-optical actuators or arrayed waveguide gratings (AWGs), respectively, a variety of requirements of the overall system polymer/substrate have to be met. Most important are the optical properties, for example refractive index and optical losses of the materials, but also technological requirements like preparation of layers and structurability as well as the thermal and thermo-mechanical stability and the long-term retention of all important parameters. For a variety of optical elements, specific requirements have to be met in addition, for example low birefringence (especially in AWGs) or variability of the refractive index by means of a circuit using applied electrodes (electro-optical and thermo-optical actuators). Especially if switching is performed thermo-optically, the thermoconductivity of the overall system polymer/substrate plays an important role for the quality of the optical element. If multiple optical elements are combined on a substrate, all requirements have to

be fulfilled for each element and each of the combinations of elements/substrates. This is very difficult.

Until now, polymethacrylates and polycarbonates have been mainly used for optical purposes. Both classes of polymers have an excellent light transmittance, but their thermal and thermo-mechanical stability is not sufficient due to their chemical structure. Thus, polymethacrylates and polycarbonates cannot practically be used at temperatures exceeding 130°C which is due to their relatively low glass transition temperatures. In addition, both types of polymers are linear, un-crosslinked polymers. This has the adverse effect that they are partly solubilized in case multilayer-systems are prepared via the application of dissolved components, e.g. by spin-coating each layer. Consequently, the layer structures as obtained are not sufficiently delimited and neat which, however, is an essential for the preparation of waveguide structures.

Increasingly used are other high performance polymers which have glass transition temperatures of more than 180°C. Examples are polyarylethersulfones, polyarylsulfones, polyaryletherketones, polyimides and polyetherimides, the processing of which, however, is more difficult than that of polymethacrylates and polycarbonates. However, they suffer from the disadvantage of relatively high optical attenuation at 1.3 μm and 1.55 μm , wavelengths which are important in communication engineering technologies.

Polyperfluorocyclobutanes (PFCB) are a relatively new class of high performance polymers. Upon thermal curing they yield unsoluble cross-linked polymers which are characterized by high thermal stability. Waveguide layers prepared from PFCB show very low optical losses of 0.2 dB/cm at 1550 nm.

Also, polycyanurates have been used for the preparation of optical components. US patents 5 208 892 and 5 165 959 describe the preparation of polycyanate resins made of a single monomer (either fluorinated or non-fluorinated). German

Offenlegungsschrift DE 44 35 992 A1 describes optical elements prepared from polycyanurate resins. Like polyperfluorocyclobutanes, polycyanurates yield unsoluble cross-linked polymers upon thermal curing, and these polymers are as well characterized by high thermal stability. They are specifically useful due to their excellent adhesional force on a variety of substrates, for example silicon, silica or a variety of organic polymers. Refractive index and glass transition temperature of the cured cross-linked polymers may be varied in broad ranges, due to the easy availability of a great number of di- and mono-functional cyanate monomers which may be copolymerized with each other. Completely cured polycyanurates known in the art which consequently are stable for long terms may have optical losses of about 0.2 dB/cm at 1.3 μ m, but not less than 0.5dB/cm at 1.55 μ m.

Specifically in case cross-linked polymers having high glass transition temperatures are used for the preparation of the optical systems to be prepared, a variety of preparation steps have to be performed at high temperatures. For example, curing of polycyanurate layers is performed at 200° to 250°C, and that of PFCB layers at 240° to 300°C. On the other hand, use of the optical systems thus prepared is in general from environmental temperature to about 80°C. If the coefficients of thermal expansion of the substrate and of the polymer layers differ from each other, for example if silicon wafers are used for the substrate, a thermal stress is developed in the layers during the repeated heating and cooling operations which result in an enormous optical birefringence or, in the worst case, in a rupture or scaling of the optical layer(s) from the substrate.

In US patent 5,170,461 to Yoon et al., the preparation of thermoplastic polymer substrates for use in organopolymer electro-optical wave guides is described. The polymer substrate is fabricated using sufficiently stress-free thermoplastic transformation, e.g. injection moulding or compression moulding. As the materials, commercially available thermoplastics like polycarbonates, polyacrylates, polysulfones, polyimides and the

like are used. Onto these substrates, polymer layers are applied according to known techniques, yielding wave guide structures. The polymeres used for the optical systems show coefficients of thermal expansion which are similar to those of the substrates used by which optical systems having low stresses frozen therein and consequently having a low birefringence are obtained.

If cross-linked polymers having a high glass transition temperature are used for the preparation of the optical elements, thermoplastic substrates cannot be used in most cases. First, the substrate softens and is deformed when the layers are cured at the required high temperatures of about 200 to 300°C because thermoplastic materials in general show a too low thermostability. Second, the coefficients of thermal expansion of thermoplastic materials are usually in a range of 100 ppm higher than those of cross-linked polymers (in general about 60 ppm), resulting in the inclusion of stresses and consequently in an undesired optical birefringence at the working temperature of the optical element or system. In this regard, substrates made of thermoplastics are comparable to substrates made of silicon. Third, unmodified, e.g. thermoplastic polymer substrates for e.g. thermo-optical actuators suffer from a very low thermal conductivity which results in unfavourable temperature profiles and consequently in a bad rupturing performance. If different optical elements are to be placed on the same chip, e.g. AWGs and thermo-optical actuators, it is therefore not possible to realise an optimum layer construction for all elements.

The present invention provides thermal and thermo-mechanical long-term substrates for optical elements or systems, which have coefficients of thermal expansion adaptable to those of the optical elements. The substrates of the invention contain or consist of thermosetting plastics and have duromeric properties.

Preferably, the thermosetting plastics are selected from epoxyd resins, polycyanurate resins, polycyanate resins, bismaleimide resins and bismaleimide triazine resins or mixtures thereof.

Polycyanurate resins, polycyanate resins, or mixtures thereof are preferred. They may e.g. be prepared from resins ("reactive resins") selected from the group comprising epoxides (e.g. Araldit LY 556 from Ciba Speciality Chemicals Inc),
5 polycyanurates or polycyanates (e.g. AroCy B-10 from Lonza AG), bismaleimides (e.g. Compimide 796 from Technochemie), bismaleimide triazine resins (e.g. BT2400 from Mitsubishi Gas Chemical Comp., Inc.) and the like or mixtures of such resins which partly are commercially available and partly known from
10 the literature.

In one embodiment of the invention, substrates are provided which have at least partly an increased thermal conductivity, compared to usual organic polymers as mentioned above, in order
15 to provide substrates which may be used to carry parts of AWG's like thermo-optical actuators or the like for which a suitable thermal conductivity of the substrate is required. In this case, the substrates contain or consist of a thermosetting plastic in combination with a material having a higher thermal conductivity
20 than said thermosetting plastic.

In an specific embodiment, the invention provides a substrate having different thermal conductivity in different parts of the substrate.

25 Usually, the substrates are easy to prepare and can be polished, and the application and processability of polymer layers onto the substrates in order to provide optical elements or systems, e.g. wave guide structures, is possible according to common
30 methods.

In cured condition, the thermosetting plastics used according to the invention are duromers and show glass transition temperatures which exceed the temperatures required for
35 application of the optical layers to be applied thereon during preparation of the optical systems. Preferably, they are in a range of 150 - 350°C, more preferable not less than 200°C.

The substrates of the optical systems according to the present invention can be prepared by casting, preferably by curing the respective reactive resins in a casting mould. Injection moulding or compression moulding should be avoided. Casting moulds may be open or sealed.

Figure 1 shows an open casting mould for the preparation of substrates according to the present invention. The reference numbers are as follows: On an adjustable ground-plate 1, a PTFE-plate 2 and a steel-plate 3 are locked together with lockings 4 and 4'. The diameter d of the mould may be e.g. 3" (7,62 cm). The thickness of the mould may be about 1 mm.

Figure 2 shows a sealed mould for the preparation of substrates according to the present invention. On a ground-plate 1, two aluminum-plates 2 are mounted which are spaced by an PTFE-distance holder 3. The aluminum-plates and the distance holder are connected by locking screws 4. The inside dimension may be e.g. 10 cm x 20 cm x 2 mm.

For the preparation of the substrate of the invention, the uncured resin (if necessary after liquefification by applying sufficient heat) is casted into a suitable mould. If necessary or favorable, a vacuum or a reduced pressure is applied, e.g. using a vacuum drying oven. Subsequently, the resin is cured using a suitable temperature or temperature profile. Not more but very little mechanical stress in the moulded articles is obtained by low cooling of the moulds until environmental temperature is reached. After demoulding, the obtained substrates may be mechanically treated or machined, e.g. cut, sawed, milled or sinked. In accordance to the requirements of the surface to be met in order to ensure correct application of the optical layers, the surface may be polished using common methods which are e.g. known from the technology of silicon wafers.

The coefficient of thermal expansion of the substrate may be adapted to that of the optical element(s) or layer(s) applied thereon in different ways. First, it is possible to mix more than one of the "reactive" resins (i.e. those which upon curing would yield duromers) having different coefficients of thermal expansion. By this way, a thermosetting plastic having the desired value thereof may be obtained. Further, the resins of the present invention yielding thermosetting plastics may be mixed with thermoplastic materials. The thermoplastic materials are preferably selected from polyimides (e.g. Matrimid 5218 from Ciba Speciality Chemicals Inc.), polyetherimides (e.g. Ultem® 1000 from General Electric), polyethersulfones (e.g. Victrex® 5003P from ICI), polysulfones (e.g. Udel® 1800P from Amoco), polyarylates (e.g. Ardel® D100 from Amoco), polycarbonates (e.g. Merlon® from General Electric), polyesters (e.g. Vitel 3200 from Bostik). Alternatively or in addition, the thermosetting plastics may be mixed with elastomeres, e.g. Hycar® HTBN or Hycar® ATBN from BF Goodrich, polytetrahydrofuran (e.g. CD 2000 from BASF), or polyurethane (e.g. Desmodur E23 from Bayer AG). Both kinds of additives result in an increase of the coefficient of thermal expansion. If mixtures are used which do not show a macroscopic phase separation, the ratio of thermosetting plastics and thermoplastic material/elastomeric material may be selected as desired, thereby allowing to adjust the coefficient of thermal expansion as needed in the whole range between that of the thermosetting plastic and that of the thermoplastic/elastomeric material. Of course, the ratio of thermoplastic material has to be chosen in such a way that the duromeric properties of the substrate is maintained. Preferably, the thermosetting plastic is present in the mixture in an amount of at least about 30% by weight, more preferably of at least about 50% per weight.

On the other hand, if the coefficient of thermal expansion shall be lowered, this may be obtained by mixing the thermosetting plastic(s) with materials like glass, ceramics, metal, graphite, carbon black and/or others which may be incorporated as powders, woven or non-woven textiles, e.g. fleeces or webs. If sufficient

thermosetting plastic is used as a binder between these additional elements, the strength of the substrate is satisfactory. In order to obtain such a strength, preferably at least 5 wt.-% and more preferably more than 50 - 99 wt.-% of the thermosetting plastic is used in this mixture. Due to the broad range of mixing ratio, the coefficient of thermal expansion may be adjusted as required in the whole range between that of that of the thermosetting plastic and that of the filling material.

To increase the thermal conductivity of the substrate, the thermosetting plastic can be mixed with materials like metals or alloys, e.g. copper, silver, or any other suitable metal having a good thermal conductivity, carbon black, graphite and others. Again, such substances may be used as powders, granules, flakes, woven or non-woven textiles (fleeces) and the like.

In order to maintain a sufficient strength of the substrate, preferably more than 20-50 wt.-% of the thermosetting plastic is used in this mixture.

In addition to the thermal conductivity varying substance(s), thermoplastic or elastomeric material can be incorporated into the mixture. Thus, the coefficient of thermal expansion may be adjusted together with that of the thermal conductivity, as desired.

In a specific embodiment, a substrate is provided having different coefficients of thermal expansion and/or thermal conductivity in different areas of the substrate, the latter being preferred. Such substrates may be obtained by a partial modification of the materials used for the substrate as described above, but only in specific areas of the substrate. Preferably, the resin is cured in an open mould (see figure 1). Materials like those exemplified above for the respective modification are applied into the desired specific areas of this mould as required. These materials may have the form of powders, flakes, granules, woven or non-woven textiles and the like. If thermoplastic or elastomeric materials as described above shall

be introduced, this may be done using high viscous molten charges. Alternatively or in addition, molten charges of thermoplastic or elastomeric materials may be used into which a suitable powder has been suspended. This embodiment may be used if fixation of the powder (e.g. one of those mentioned above) at specified areas is desired. After introduction of the materials as described above, the mould is filled with resin which upon curing yields a thermosetting material. After curing of the substances present in the mould, a substrate having areas of different coefficient of thermal expansion and/or of thermal conductivity is obtained.

The invention is now further illustrated by way of examples:

Example 1

6g AroCy® B-10 (Lonza AG) are heated to 90°C in a round bottomed flask and the melted material is degassed at 2-3 kPa for 30 min. The melt is poured into a casting mould as shown in figure 1, having an inner diameter d of 3" (7,62 cm) and a thickness of about 1 mm. Subsequently, the mould is brought into a drying oven in order to cure the resin. The temperature profile applied is: 20 h at 180°C, 30 min to reach 200°C, 1h at 200°C, 30 min to reach 220°C, 1 h at 220°C, 30 min to reach 240°C, 1 h at 240°C, 30 min to reach 260°C, 1 h at 260°C, 30 min to reach 280°C, 1 h at 280°C, cooling to room temperature with a rate of 0.5 K/min. After releasing the substrate from the mould, the rim is trimmed using abrasive paper, and a firm, stable disc or plate is obtained, having 3" diameter and a thickness of 1 mm. Then, the already very smooth surface of the disc is polished using fine-grained abrasive.

7.3 g of 2,2'-bis(4-cyanatophenyl) hexafluoropropane and 2.7 g of 2,2'-bis(4-cyanatophenyl) propane are heated to 180 °C in a sealed vessel for a time of about five hours. The reaction is terminated before gelling starts, and a clear, pale yellow prepolymer is obtained which is viscous at 180°C and is solid at room temperature. The prepolymer is brought into solution by

mixing it with 50 % by weight of ethylethoxyacetate. Spin-coating of this solution onto the polymeric substrate described above as well as onto a substrate made of silicon yields layers which can be cured at 240°C for one hour in a drying oven. The layer on the silicon substrate has a birefringence of 0.004 and the layer on the polymeric substrate has a birefringence of 0.0005 at a wavelength of 1.55 μm .

Example 2

5g AroCy® B-10 (Lonza AG) are heated to 90°C in a round bottomed flask and the melted material is degassed at 2-3 kPa for 30 min. The melt is poured into a casting mould as shown in figure 1, having an inner diameter $d=3"$ (7,62 cm) and a thickness of about 1 mm. 1 g of a mixture of 60 wt-% copper powder and 40 wt-% AroCy® L-10 (Lonza AG) are poured to that area in the casting mould in which a different thermal conductivity shall be obtained, compared to the remaining areas of the substrate. Subsequently, the polymer is cured in a drying oven. The temperature profile applied is: 20 h at 180°C, 30 min to reach 200°C, 1h at 200°C, 30 min to reach 220°C, 1 h at 220°C, 30 min to reach 240°C, 1 h at 240°C, 30 min to reach 260°C, 1 h at 260°C, 30 min to reach 280°C, 1 h at 280°C, cooling to room temperature with a rate of 0.5 K/min. After releasing the substrate from the mould, the rim is trimmed using abrasive paper, and a firm, stable disc or plate is obtained, having 3" diameter and a thickness of 1 mm. A delimited area can be seen on the disk which contains the copper powder. Optional, the already very smooth surface of the disc may be polished using fine-grained abrasive. The substrate thus obtained may be used in the preparation of optical systems (e.g. comprising optical multi-layers), for example using processing steps like spin-coating, thermocuring, RIE-etching and the like, as it is known for the processing of silicon wafers.

Example 3

53 g of a mixture of 41.5 wt.-% bisphenol A diglycid ether, 37.5 wt.-% tetrahydrophthalic anhydride, 1 wt.-% dimethylbenzylamine and 20 wt.-% Hycar® HTBN (BF Goodrich) are heated to temperature of 70°C in a round bottomed flask, and the melt is degassed at 2-3 kPa for 30 min. The melt is cast into a sealable casting mould (Figure 2) having inner dimensions of 22x12x0.15 cm and is cured in a drying oven; temperature profile: 5 h at 80°C, 30 min to reach 120°C, 1 h at 120°C, 30 min to reach 140°C, 1 h at 140°C, 30 min to reach 160°C, 1 h at 160°C, and cooling to environment temperature at a rate of 0.5 K/min. After releasing from the mould, a stable plate is obtained. Two discs having a diameter of 4" (10.16 cm) are cut from the plate, using a lead saw. Both surfaces of the disc are polished several times using an abrasive of consecutively finer grains. The substrate thus obtained may be used in the preparation of optical systems (e.g. comprising optical multi-layers), for example using processing steps like spin-coating, thermocuring, RIE-etching and the like, as it is known for the processing of silicon wafers.

Claims:

1. Use of a thermosetting plastic as a substrate material in optical systems.
2. Use according to claim 1 , wherein the thermosetting plastic is selected from at least one of the group consisting of polycyanurate resins, polycyanate resins, or mixtures thereof.
3. Use according to claim 1 or 2, wherein the thermosetting plastic has a glass transition temperature of not less than 150°C, preferably of not less than 200°C, more preferably of not less 250°C and most preferably not less than 300°C.
4. Use according to any of claims 1 to 2, wherein the substrate material additionally contains at least one of a thermoplastic material and an elastomeric material.
5. Use according to claim 4, wherein the thermoplastic material is selected from polyimides, polyetherimides, polyethersulfones, polysulfones, polyarylates, polycarbonates, polyesters and mixtures of these polymers and/or wherein the elastomeric material is selected from acrylonitrile-butadiene, acrylonitrile-butadiene-styrene, polyesters and polyurethanes.
6. Use according to any of the preceding claims, wherein the substrate material additionally contains at least one material having a higher thermal conductivity than said thermosetting plastic.
7. Use according to claim 6 wherein the material having a higher thermal conductivity than said thermosetting plastic is selected from the group of metals or alloys, carbon black, and graphite, and preferably from silver and/or copper.

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art. 34 Amendment

8. Use according to claim 6 or 7 wherein the material having a higher thermal conductivity is incorporated into the thermosetting in the form of a powder, a granulate, of flakes or of woven or non-woven textiles.
- 5 9. Use according to any of claims 6 to 8 wherein the material having a higher thermal conductivity is incorporated into the thermosetting only into restricted areas of the substrate.
10. Use according to any of the preceding claims, wherein the substrate material additionally contains at least one
10 material which lowers the coefficient of thermal expansion of the thermosetting plastic, the said material preferably selected from glass, ceramics, metal, graphite and carbon black.
11. Use according to claim 1 wherein the optical system is a
15 waveguide system or an electro-optical actuator or a thermo-optical actuator.
12. Process for the preparation of a substrate for optical systems, wherein a liquid which upon curing forms a thermosetting plastic, is casted into a casting mould, the
20 casting mould is optionally sealed, the resin is optionally degassed by applying a vacuum, and the resin is cured by applying a suitable temperature or temperature profile.
13. Process according to claim 12, wherein at least one
25 material, selected from materials having a higher thermal conductivity than said thermosetting plastic, thermoplastic materials, elastomeric materials and materials which lower the coefficient of thermal expansion of the thermosetting plastic is added to the liquid.

- 14 Process according to claim 12 or 13 wherein a material which lowers the coefficient of thermal expansion of the thermosetting plastic is added to the resin which upon curing will form a thermosetting plastic, the said material
5 preferably selected from glass, ceramics, metal, graphite, carbon black.
15. Process according to any of claims 12 or 13 wherein the thermoplastic material and/or the elastomeric material and/or the material which lowers the coefficient of thermal
10 expansion of the thermosetting plastic and/or the material having a higher thermal conductivity is added by placing it only into predetermined restricted areas of the mold.
16. Process according to claim 13, wherein the material is added only after the liquid has been brought into the casting
15 mould, and preferably only into predetermined restricted areas of the said mould.
17. Optical system, comprising a substrate material and at least one optical element applied thereto, wherein the substrate material is a thermosetting plastic.
- 20 18. Optical system according to claim 17 which is an optical waveguide system or an electro-optical actuator or a thermo-optical actuator.
19. Optical system according to claims 17 or 18, wherein the thermosetting plastic has a glass transition temperature of
25 not less than 150°C, preferably of not less than 200°C, more preferably of not less than 250°C, and most preferably not less than 300°C and/or is selected from at least one of the group consisting of polycyanate resins, polycyanurate resins, and mixtures thereof.

20. Optical system according to any of claims 17 to 19, wherein the substrate material consists of the said thermosetting plastic and at least one thermoplastic material, preferably selected from polyimides, polyetherimides, polyethersulfones, polysulfones, polyarylates, polycarbonates, polyester and mixtures of these polymers, and/or at least one elastomeric material, preferably selected from acrylonitrile-butadiene, acrylonitrile-butadiene-styrene, polyesters and polyurethanes.
21. Optical system according to any of claims 17 to 20, wherein at least one optical element applied to the substrate is prepared from or using an organic polycyanate and/or PFCB.
22. Optical system according to any of claims 17 to 21, wherein at least one optical element applied to the substrate is prepared from or using an organic polycyanate and/or PFCB.
23. Optical system according to claim 22, wherein the organic polycyanate is a (co)polymerisate of at least one aromatic dicyanate.
24. Optical system according to claim 23, wherein the organic polycyanate is a copolymerisate of a fluor-free aromatic dicyanate and a fluor-containing aromatic dicyanate.

Claims:

1. Use of a thermosetting plastic as a substrate material in optical systems.
2. Use according to claim 1 , wherein the thermosetting plastic is selected from at least one of the group consisting of polycyanurate resins, polycyanate resins, or mixtures thereof.
3. Use according to claim 1 or 2, wherein the thermosetting plastic has a glass transition temperature of not less than 150°C, preferably of not less than 200°C, more preferably of not less 250°C and most preferably not less than 300°C.
4. Use according to any of claims 1 to 2, wherein the substrate material additionally contains at least one of a thermoplastic material and an elastomeric material.
5. Use according to claim 4, wherein the thermoplastic material is selected from polyimides, polyetherimides, polyethersulfones, polysulfones, polyarylates, polycarbonates, polyesters and mixtures of these polymers and/or wherein the elastomeric material is selected from acrylonitrile-butadiene, acrylonitrile-butadiene-styrene, polyesters and polyurethanes.
6. Use according to any of the preceding claims, wherein the substrate material additionally contains at least one material having a higher thermal conductivity than said thermosetting plastic.
7. Use according to claim 6 wherein the material having a higher thermal conductivity than said thermosetting plastic is selected from the group of metals or alloys, carbon black, and graphite, and preferably from silver and/or copper.

8. Use according to claim 6 or 7 wherein the material having a higher thermal conductivity is incorporated into the thermosetting in the form of a powder, a granulate, of flakes or of woven or non-woven textiles.
- 5 9. Use according to any of claims 6 to 8 wherein the material having a higher thermal conductivity is incorporated into the thermosetting only into restricted areas of the substrate.
10. Use according to any of the preceding claims, wherein the substrate material additionally contains at least one
10 material which lowers the coefficient of thermal expansion of the thermosetting plastic, the said material preferably selected from glass, ceramics, metal, graphite and carbon black.
11. Use according to claim 1 wherein the optical system is a
15 waveguide system or an electro-optical actuator or a thermo-optical actuator.
12. Process for the preparation of a substrate for optical systems, wherein a liquid which upon curing forms a thermosetting plastic, is casted into a casting mould, the
20 casting mould is optionally sealed, the resin is optionally degassed by applying a vacuum, and the resin is cured by applying a suitable temperature or temperature profile.
13. Process according to claim 12, wherein at least one material, selected from materials having a higher thermal
25 conductivity than said thermosetting plastic, thermoplastic materials, elastomeric materials and materials which lower the coefficient of thermal expansion of the thermosetting plastic is added to the liquid.

- 14 Process according to claim 12 or 13 wherein a material which lowers the coefficient of thermal expansion of the thermosetting plastic is added to the resin which upon curing will form a thermosetting plastic, the said material
5 preferably selected from glass, ceramics, metal, graphite, carbon black.
15. Process according to any of claims 12 or 13 wherein the thermoplastic material and/or the elastomeric material and/or the material which lowers the coefficient of thermal
10 expansion of the thermosetting plastic and/or the material having a higher thermal conductivity is added by placing it only into predetermined restricted areas of the mold.
16. Process according to claim 13, wherein the material is added only after the liquid has been brought into the casting
15 mould, and preferably only into predetermined restricted areas of the said mould.
17. Optical system, comprising a substrate material and at least one optical element applied thereto, wherein the substrate material is a thermosetting plastic.
- 20 18. Optical system according to claim 17 which is an optical waveguide system or an electro-optical actuator or a thermo-optical actuator.
- 25 19. Optical system according to claims 17 or 18, wherein the thermosetting plastic has a glass transition temperature of not less than 150°C, preferably of not less than 200°C, more preferably of not less than 250°C, and most preferably not less than 300°C and/or is selected from at least one of the group consisting of polycyanate resins, polycyanurate resins, and mixtures thereof.

20. Optical system according to any of claims 17 to 19, wherein the substrate material consists of the said thermosetting plastic and at least one thermoplastic material, preferably selected from polyimides, polyetherimides, polyethersulfones, polysulfones, polyarylates, polycarbonates, polyesters and mixtures of these polymers, and/or at least one elastomeric material, preferably selected from acrylonitrile-butadiene, acrylonitrile-butadiene-styrene, polyesters and polyurethanes.
21. Optical system according to any of claims 17 to 20, wherein at least one optical element applied to the substrate is prepared from or using an organic polycyanate and/or PFCB.
22. Optical system according to any of claims 17 to 21, wherein at least one optical element applied to the substrate is prepared from or using an organic polycyanate and/or PFCB.
23. Optical system according to claim 22, wherein the organic polycyanate is a (co)polymerisate of at least one aromatic dicyanate.
24. Optical system according to claim 23, wherein the organic polycyanate is a copolymerisate of a fluor-free aromatic dicyanate and a fluor-containing aromatic dicyanate.

* * *

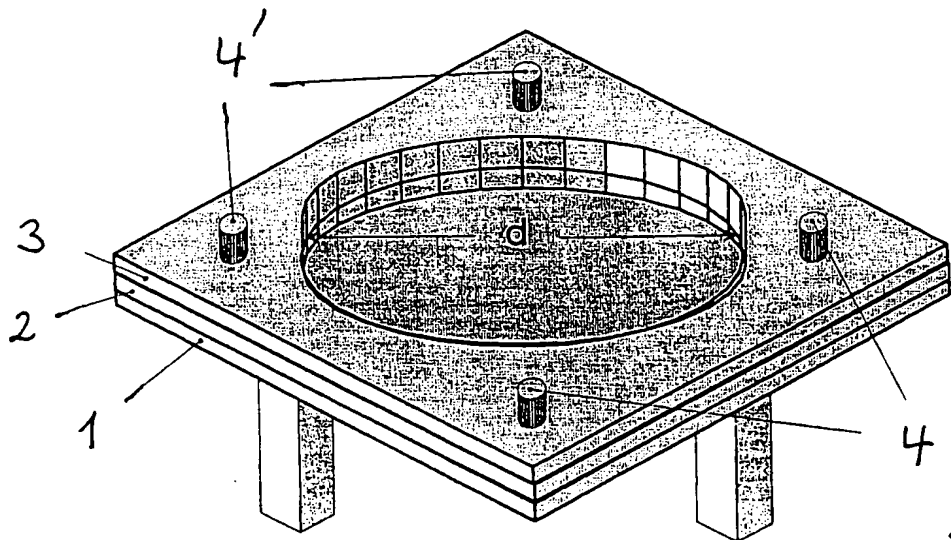


Figure 1

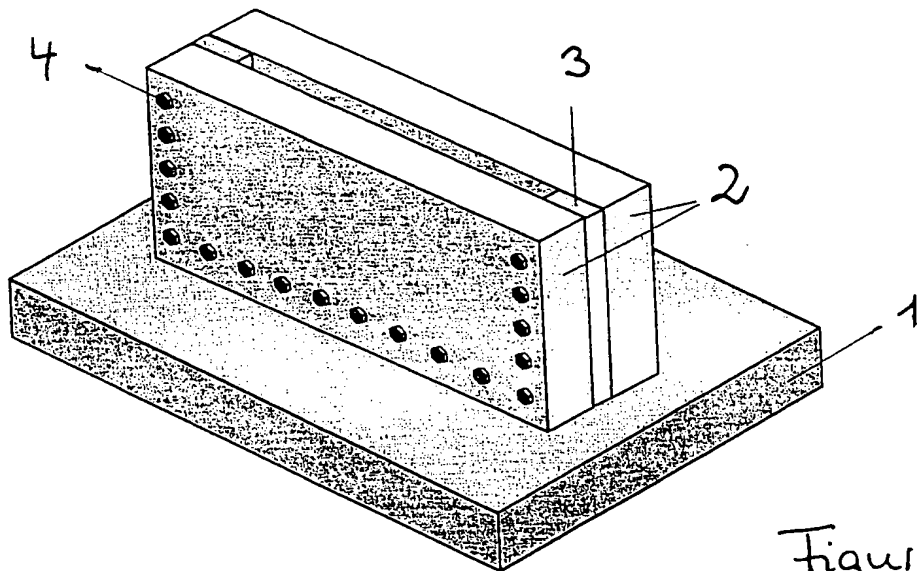


Figure 2

INTERNATIONAL SEARCH REPORT

International Application No

PCT/EP 00/06202

A. CLASSIFICATION OF SUBJECT MATTER

IPC 7 G02B1/04

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 G02B

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

WPI Data, PAJ, EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

* Special categories of cited documents :

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Date of the actual completion of the international search

31 October 2000

Date of mailing of the international search report

13/11/2000

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INTERNATIONAL SEARCH REPORT

International Application No
PCT/EP 00/06202

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